5A.4 PRELIMINARY HIGH-RESOLUTION DUAL-DOPPLER ANALYSES OF TWO TORNADIC THUNDERSTORMS

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1. INTRODUCTION

Tornadoes and tornadic thunderstorms have been the subject of much research over the past 30 years, and great knowledge has been gained through observations (e.g., Lemon and Doswell 1979; Brandes 1984; Bluestein et al. 1993; Wakimoto and Atkins 1996; Dowell and Bluestein 1997; Wurman and Gill 2000, Bluestein and Pazmany, 2000), numerical simulations (e.g., Klemp and Rotunno 1983; Wicker and Wilhelmson 1995; Adlerman et al. 1999) and theory (e.g., Lewellen 1993; Davies-Jones 1986; Trapp and Davies-Jones 1997). However, many of the theoretical and numerical simulation results remain unverified due to a paucity of high-resolution observations near tornadoes.

In this study, we examine the structure of two thunderstorms with mature tornadoes using high-resolution, dual-Doppler radar data obtained by the Doppler on Wheels (DOW) radars.

2. RADAR SPECIFICATIONS

The Doppler On Wheels (DOW) mobile radars (Wurman et al. 1997, 2001) were developed expressly for obtaining high-resolution data in tornadoes and other small-scale and short-lived phenomena. The current DOWs can scan rapidly, up to 60°s^{-1}, produce pulses of < 200 ns and sample signals every 83 ns to obtain oversampled range resolution of 12.5 m and non-oversampled resolution of 25 m. The DOWs operate at approximately 9.375 GHz, with peak transmitted power of 250 kW, and beam widths of 0.93°. Although the beamwidth of the DOWs is comparable to radars at fixed sites (e.g., WSR-88D), one may collect high-resolution datasets with the DOWs by setting up short dual-Doppler baselines at close range to tornadoes.

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3. TORNADIC THUNDERSTORM CASES

The first thunderstorm to be studied occurred near Bridgeport, NE on 20 May 1998. DOW2 and DOW3 deployed 14.4 and 12.8 km from the tornado, respectively, giving a baseline of 9.4 km and a beam crossing angle of approximately 40° (Fig. 1). The DOWs captured approximately 2 minutes (1.5 volumes) of high-resolution dual-Doppler data during the weakening phase of the already quite weak and brief tornado.

The second tornadic thunderstorm occurred on 3 June 1999 near Almena, KS and resulted in F3 damage. Dual-Doppler volumetric data were collected for approximately 7 minutes. Only one volume (00:37 UTC) is considered here. In this case, DOW2 and DOW3 were 14.0 and 3.0 km from the tornado, respectively, giving a baseline of 12.5 km and a beam crossing angle of 54.5° (Fig. 2).

4. DUAL-DOPPLER WIND SYNTHESIS

After the radar data have been properly edited and dealiased, they are objectively analyzed onto a common Cartesian grid, with 100 m grid spacing, using a Cressman scheme. The locations of the radars are known from GPS measurements recorded during the deployments. The heading angles of the trucks are determined using the ranges and radar-relative angles of common targets. An alternative method computes the correlation coefficient between reflectivity fields from the radars over a target region for various heading angles. The 'true' heading angles are assumed to be those giving the highest correlation coefficient (Zhang et al., 2001). For the cases considered here, the two methods gave nearly identical results.

The radii of influence, based on roughly twice the beamwidth of the farthest radar as well as the elevation angle interval, are 400 m and 500 m in the horizontal for Bridgeport and Almena, respectively, and 600 m in the vertical for both cases. When the two radars are at very different ranges from the tornado, as in the

Almena case, the radius of influence is much larger than would be required simply for eliminating noise from the DOW closest to the tornado. It is chosen to preserve roughly the same scales of motion in the data from each radar.

Because each volume consists of scans taken at slightly different times, all data are adjusted to a common time by subtracting the translational motion of the tornado. This motion is determined by tracking the low reflectivity eye in the center of the tornado (Figs. 3 and 4) at several times and heights. An average translational velocity is then computed and assumed to be constant over the domain.

After all data have been interpolated onto the Cartesian grid, a dual-Doppler analysis is performed using a two-step, second order Lax-Wendroff scheme (Sperow, 1995), with inclusion of data only in regions where the between-beam angle is greater than 30° and less than 150°.

5. RESULTS

Dual-Doppler synthesis in the Bridgeport case (Fig. 5) shows the tornado is located in a region with a strong gradient in vertical velocity, with divergence evident south of the tornado in the expected region of the rear flank downdraft. In the Almena case, the region of 'wrap-around' winds is confined to a fairly small area and inflow is evident east of the tornado in the weak reflectivity region (Fig. 6). In the Bridgeport case, however, strong outflow winds extend east of the tornado and the decaying tornado is surrounded with divergence in a manner consistent with the decay stage of simulated tornado-like vortices (Wicker and Wilhelmson 1995). The updraft associated with the tornado is disconnected from the gust front updraft and is surrounded by downdraft. Vertical vorticity analyses (not shown) indicate a secondary vortex to the east of the tornado in the Bridgeport case, suggesting cyclic mesocyclogenesis. However, no further tornadoes were observed in this storm.

6. FUTURE WORK

Having high-resolution volumetric data allows for the calculation of the tilting and stretching terms in the vertical vorticity equation. At the conference, we plan to compare vorticity analyses of the Bridgeport and Almena storms to current conceptual models of tornadic storms. Sensitivity tests to assumptions made in the analysis will also be discussed.

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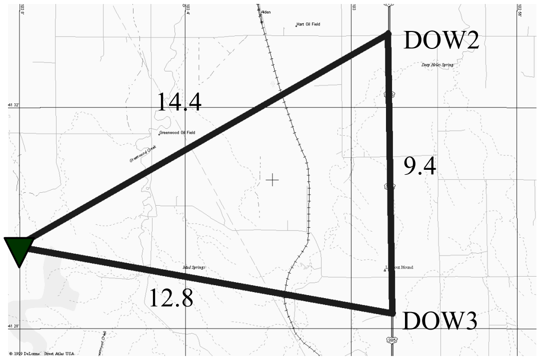

Fig. 1: Deployment near Bridgeport, NE on 20 May 1998. Triangle indicates tornado location. Distances are in km.

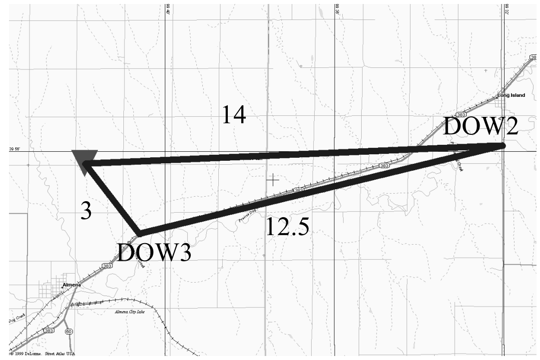

Fig. 2: Deployment near Almena, KS on 3 June 1999. Triangle indicates tornado location. Distances are in km.

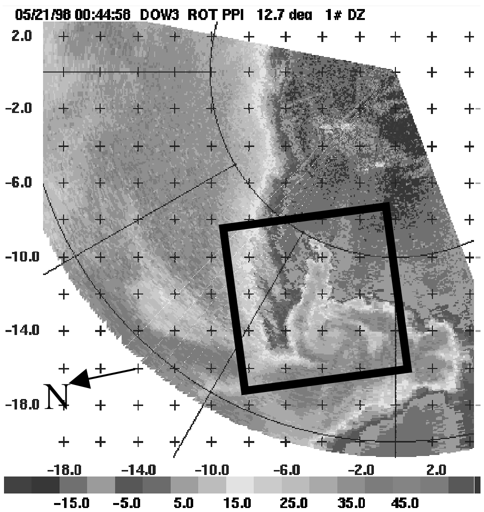

Fig. 3: Reflectivity from DOW3 at 00:44 UTC on 21 May 1998 near Bridgeport, NE. The elevation angle varies between 0.5-1.5°

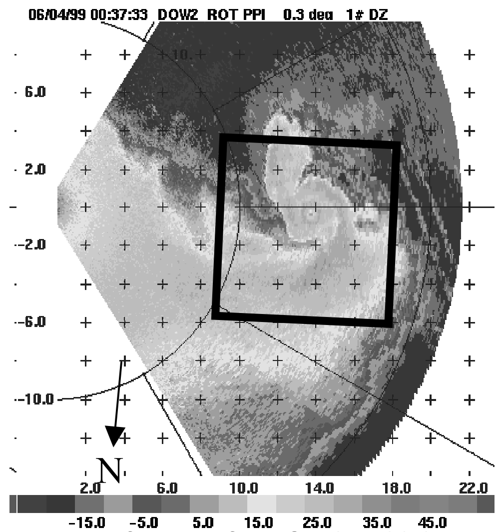

Fig. 4: Reflectivity for DOW2 at 00:37 UTC on 4 June 1999 near Almena, KS. The elevation angle is 1°.

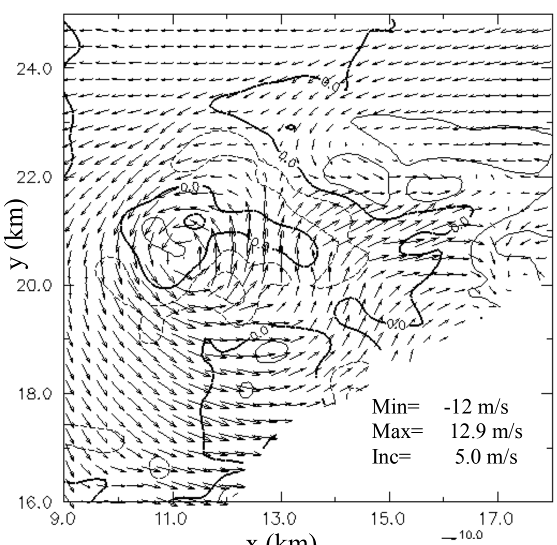

Fig. 5. Dual-Doppler analysis of vertical velocity and horizontal wind at 700 m for 20 May 1998, Bridgeport, NE tornado. Every third vector is shown. Domain as shown in Fig. 3.

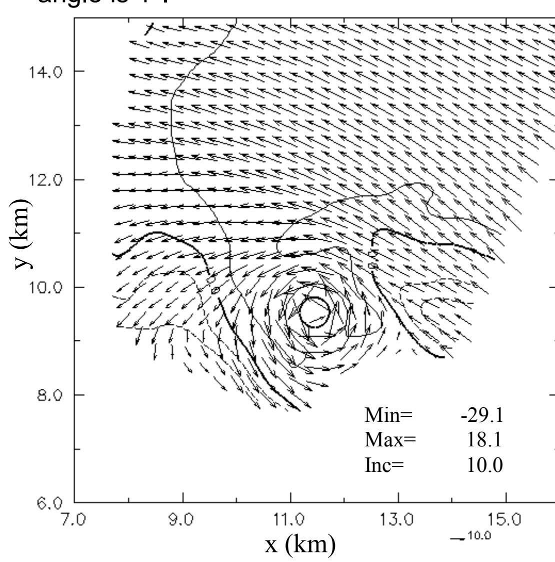

Fig. 6. Dual-Doppler analysis of horizontal winds and reflectivity at 700 m for the 3 June 1999, Almena, KS tornado. Every third vector is shown. Domain as shown in Fig. 4.